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The Effect of Inoperative Readout Layers on SDC Calorimetry

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1. Introduction

The SDC calorimeter is to be constructed using Pb and Fe absorbers and scintillator active sampling using the tile/fiber technique [1]. In this note, the effect of the inoperative readout of a single sampling layer is studied. The goal of this study is to inform on a cost/benefit analysis of the need to repair inoperative layers of the calorimetric readout.

2. Use of HF data

The "hanging file" = HF test apparatus is described elsewhere [2]. It is a reasonable approximation to the SDC central calorimeter [1]. In this note, the effect of an inoperative layer on hadronic (HAD) calorimetry is studied. HF data at a nominal energy of 250 GeV (observed mean energy $\langle E \rangle = 272.30$ GeV) were used. The data consist of calibrated readout of each layer of a 95 layer "stack". The stack has 40 plates of 1/8" Pb (22.8 Xo) followed by 55 plates of 1" Fe (79.2 Xo) interspersed with 2.5 mm plastic scintillator.

The calibration was done using 1 "mip" muons in each compartment separately; the electromagnetic (EM) and hadronic (HAD). There is one overall relative calibration of compartments. It was chosen to make the e/π response roughly energy independent [2], not to minimize the energy resolution. The EM compartment is about 22.8 Xo of Pb and 0.75 absorbtion lengths. The HAD compartment is 79.2 Xo of absorber or 8.34 absorption lengths. Typical single events due to 250 GeV incident pions are shown in Fig. 1. Clearly, the hadronic energy depositions have large fluctuations. The mean of many single events is shown in Fig.2. The curve of Fig.2 is the more conventional "mean hadronic shower depth profile". However, reference to Fig.1 shows that the large event to event fluctuations have been averaged away.

A previous study [3] came to some preliminary conclusions about the magnitude of the losses due to the existence of inoperative layers.

3. Effect of an inoperative layer on calorimeter performance

The HF stack total energy, found by adding all the layers in the stack, is shown in Fig.3 for 250 GeV incident pions. The mean is, $<E> = 272.3$ GeV, while the second moment, the rms is, $dE = 14.42$ GeV. The fractional energy error is then, $dE/E = 0.053$.

It is assumed that the calorimeter as an energy measuring device is defined by the first and second moments of the reported energy distribution. A broken tile is simulated by dropping one of the 95 independent scintillator readouts from the total energy sum.

The effect of this procedure on the mean of the energy is shown in Fig 4. For layers < 40 (EM compartment) and layers > 70 (HAD2 compartment) [1], the loss of a layer causes a shift of < 1% in the energy response. The maximum shift, occuring at the shower maximum as shown in Fig. 2, is 5.5%. Note that Fig. 2 and Fig. 4 are essentially the same in shape, as they should be. In fact, the peak value/layer is ~ 12 GeV, which contributes ~ 5% to the energy sum. Hence, a failure of this layer would cause an average shift of ~ 5% in the energy mean. It should be noted that, if the failure of the layer is detected, for example by moving radioactive sources as are planned for the SDC calorimeters [1], then the tower may be recalibrated knowing the location of the failure, using Fig. 4.

The procedure outlined above evades the effect of the broken layer on the mean. However, the fluctuations on showers about that mean, see Fig. 1, cannot be evaded, nor easily corrected for. In Fig. 5 is shown the effect of a broken layer on the rms of the energy distribution. For layers < 40 (EM) and > 70 (HAD2) there are < 5% increases in the rms of the energy. However, the region around the EM/HAD boundary is very sensitive. If the dropped tile is in the first few readout layers in the HAD compartment, then the resolution suffers an increase of up to 22%. In contrast, if a layer near the hadronic shower maximum is dropped, the resolution actually improves.

The explanation for this behavior is that the SDC calorimeter is a composite object. It consists of Pb and Fe absorbers. As stated above, the relative calibration of the EM and HAD compartments was floated such to make the electron/π response near to 1 and nearly energy independent. This choice of calibration does not minimize the energy resolution [2]. Therefore, it is not implausible that the rms might actually be reduced by imposing a different effective calibration by dropping 1 layer from the HAD energy sum. Note also that the character of the electromagnetic component of the hadronic shower changes at the Pb/Fe boundary since the relative radiation length/absorption length differs greatly in the 2 materials. The critical energy, which defines the cutoff energy of an electromagnetic shower [4], also differs greatly as it scales roughly as 1/Z.

Therefore, the integrity of the readout in a composite calorimeter such as that proposed by SDC is important at the Fe/Pb boundary. It is expected that a homogeneous calorimeter structure would not exhibit the same measure of sensitivity to the boundary between readout compartments.

REFERENCES

1. SDC Technical Design Report, SDC-92-101 (1992).
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3. D. Green, "Dead Material and Energy Measurements in Hadronic Calorimeters", Fermilab-TM-1824, January 1993.
4. Review of Particle Properties, *Phys. Rev.* D 45 (1992).

FIGURE CAPTIONS

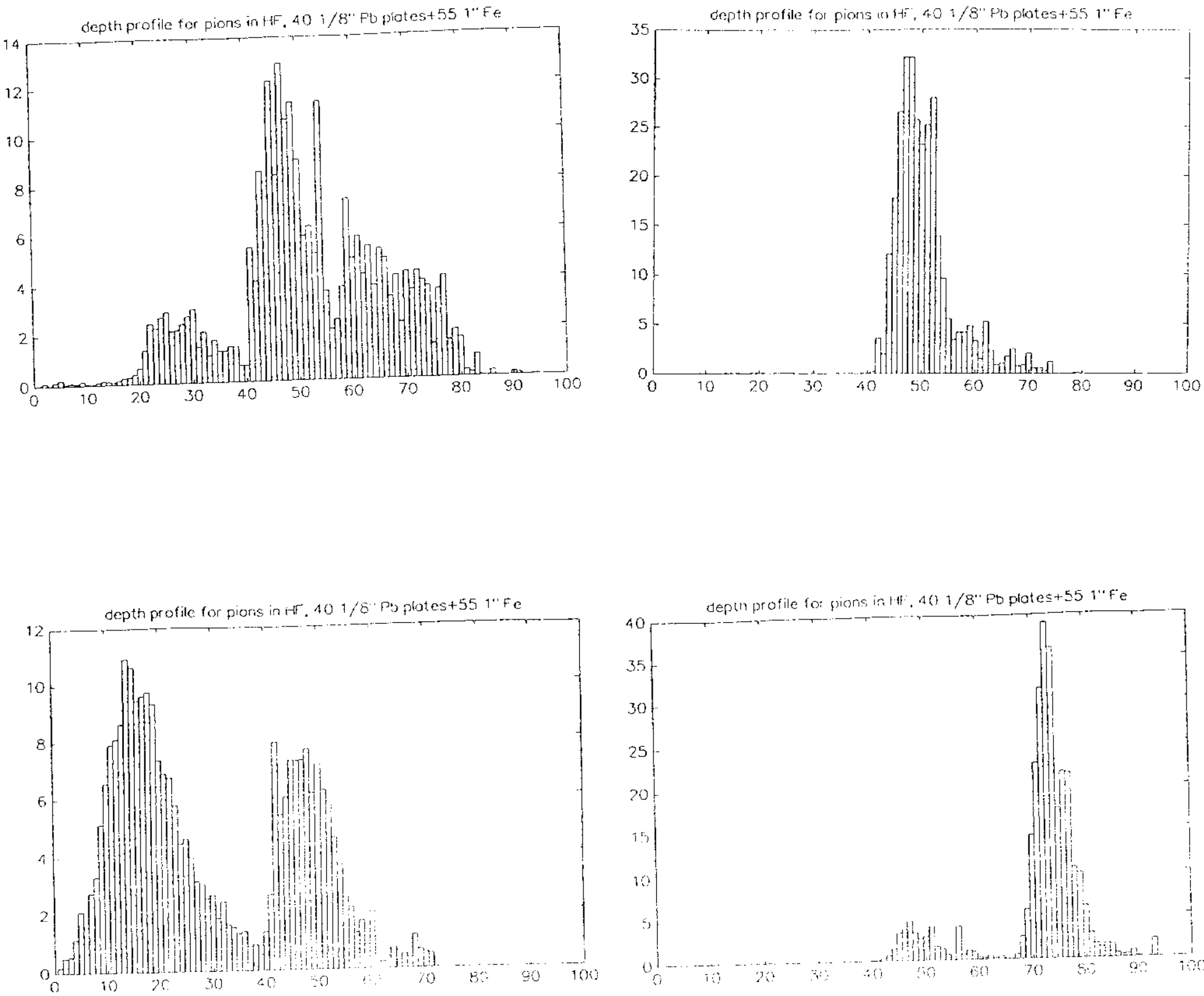
Fig. 1 Depth profile in the HF stack for 250 GeV incident pions. The first 4 events in a file were chosen. The fluctuations in the hadronic shower shapes are quite evident.

Fig. 2 The average depth profile, obtained by summing the individual profiles shown in Fig. 1 for many incident pions. Note that the fluctuations are smoothed out, and the transition from EM to HAD compartment at plate #40 is evident.

Fig. 3 Energy response of the calorimeter obtained from summing the 95 readout layers of the entire HF stack. The mean is, $\langle E \rangle = 272.30$ GeV and the rms is $dE = 14.42$ GeV, or $dE/E = 0.053$.

Fig. 4 Mean energy with 1 inoperative layer at location = j in the stack, scaled to the mean of the intact stack, $\langle E(j) \rangle / \langle E \rangle$, as a function of j.

Fig. 5 The rms energy with 1 inoperative layer at location = j in the stack, scaled to the rms of the intact stack, $dE(j)/dE$, as a function of j.



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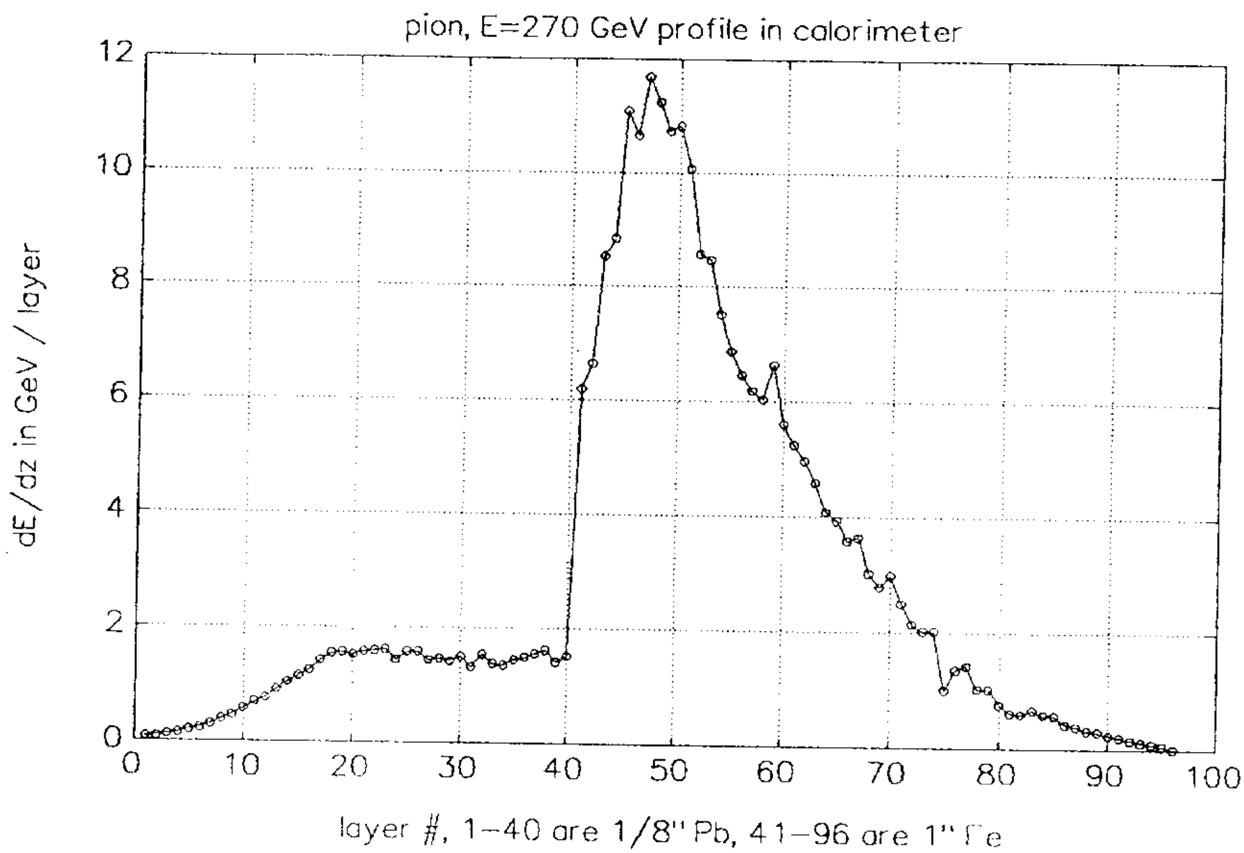
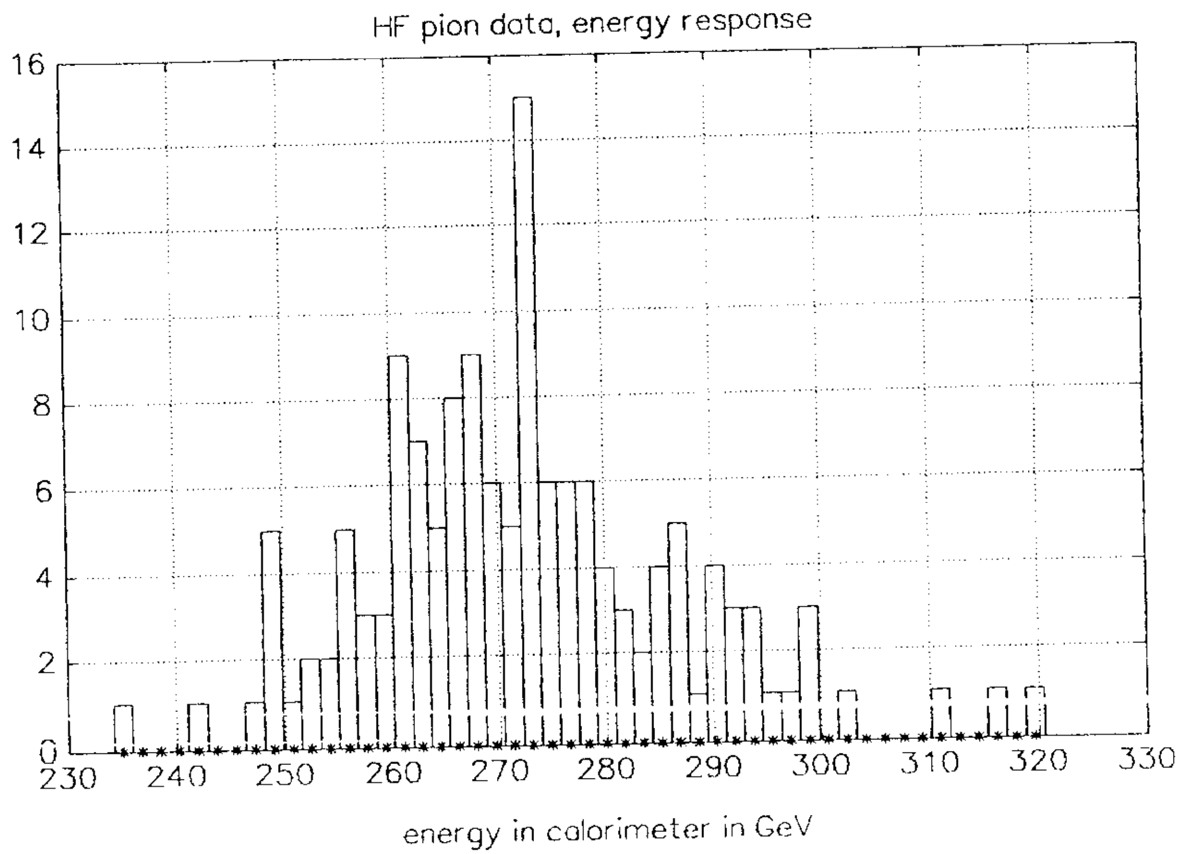


Fig. 2 The average depth profile, obtained by summing the individual profiles shown in Fig. 1 for many incident pions. Note that the fluctuations are smoothed out, and the transition from EM to HAD compartment at plate #40 is evident.



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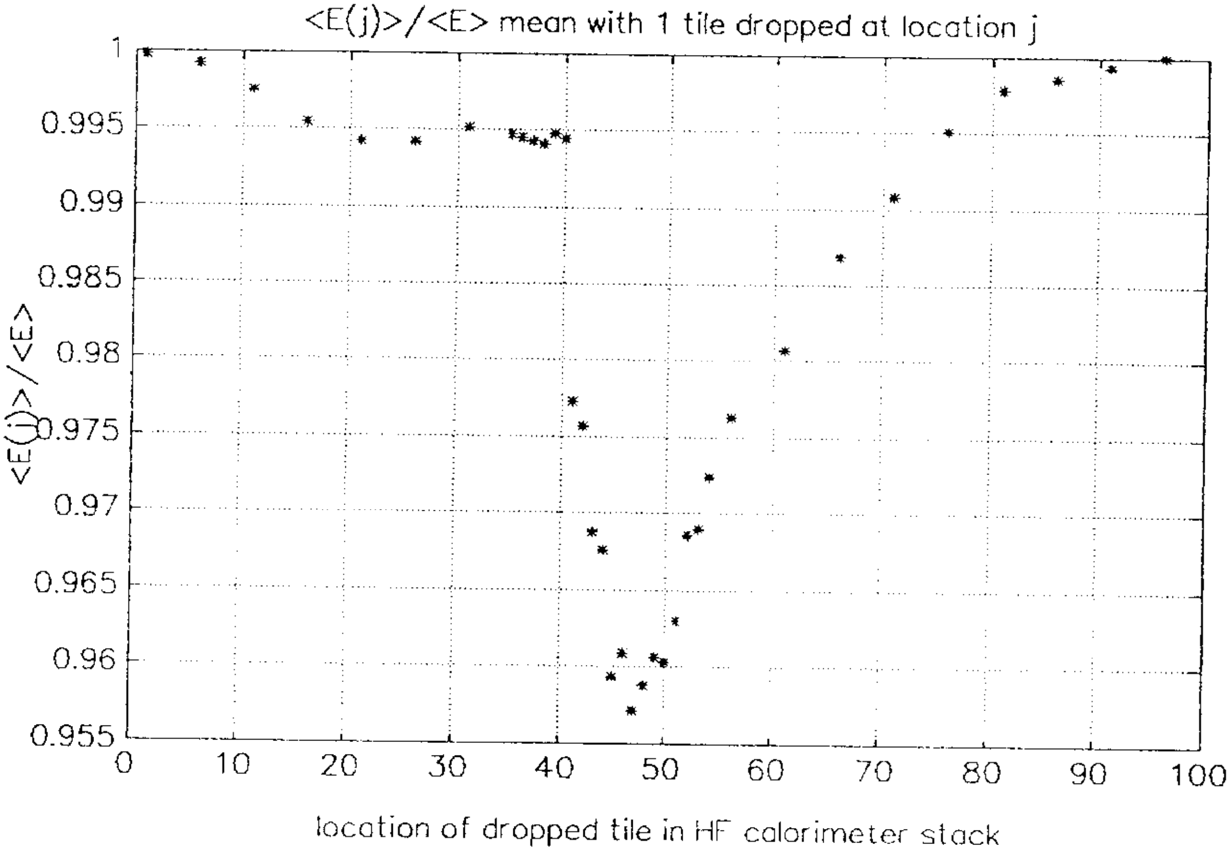

Fig. 4 Mean energy with 1 inoperative layer at location = j in the stack, scaled to the mean of the intact stack, <E(j)>/<E>, as a function of j.

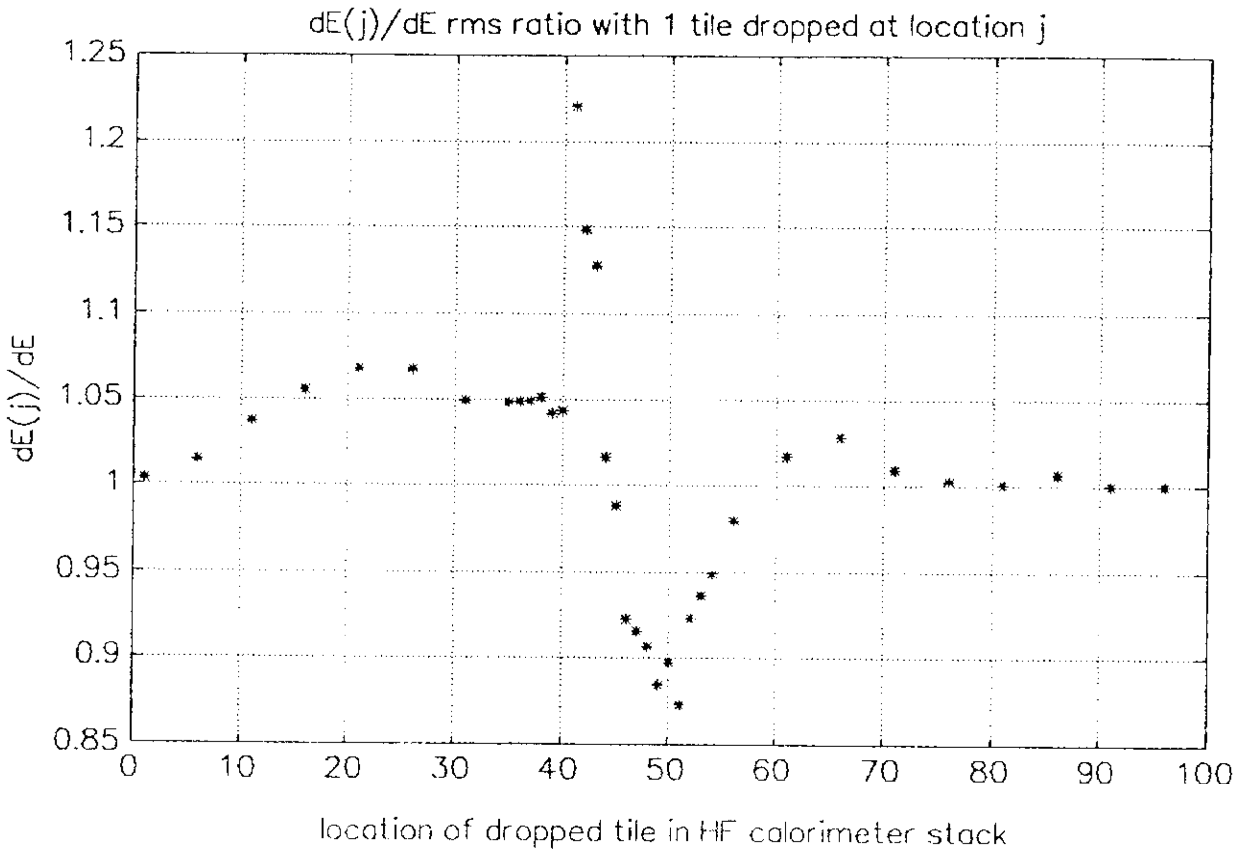

Fig. 5 The rms energy with 1 inoperative layer at location = j in the stack, scaled to the rms of the intact stack, dE(j)/dE, as a function of j.